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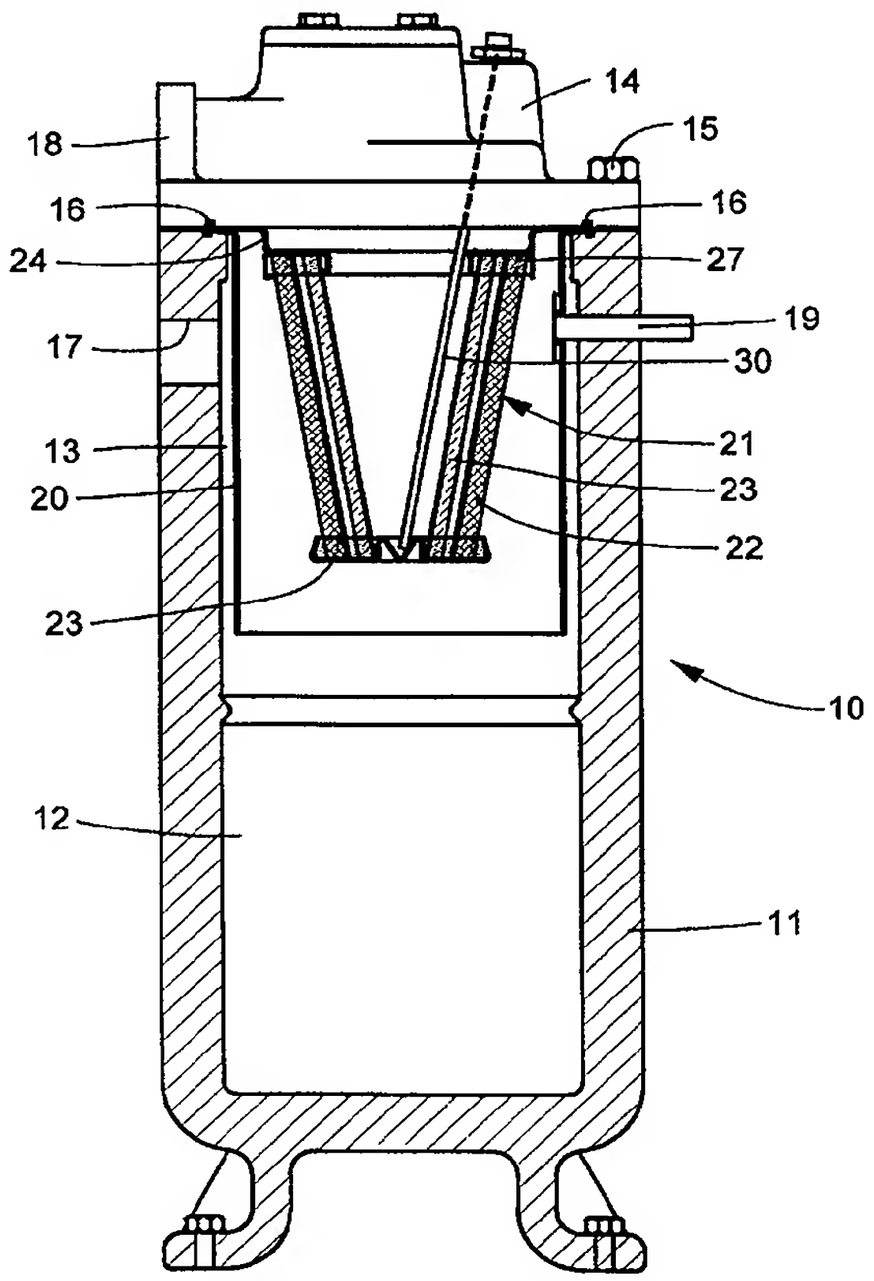
(54) **Title:** CONICALLY SHAPED AIR–OIL SEPARATOR

(57) **Abstract**

A liquid reservoir tank assembly (10) includes a gas–liquid separator (21), which has particular application as an air–oil separator. A tank body (11) has an open end, a portion of the tank body forming a liquid separation chamber (13), another portion of the tank body forming a liquid reservoir (12). A tank cover (14) covers the open end of the tank body, the tank body and the tank cover providing a gas inlet (17) and a gas outlet (18) with a gas flow through the separation chamber from the gas inlet to the gas outlet. The gas–liquid separator (21) is mounted in the separation chamber in the gas flow between the gas inlet and the gas outlet. The separator has a coalescing stage layer (22) and a drain stage layer (23) arranged radially symmetrically about an axis extending through the interior of the separator. One of the layers is positioned within the other of the layers. The coalescing stage layer is upstream of the drain stage layer. Each of the layers is generally frustoconical in shape whereby both of the layers are closer to the axis at one end than at the other end.



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CONICALLY SHAPED AIR-OIL SEPARATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to filtering of liquids from gaseous streams, and more particularly to air-oil separators such as those used to remove suspended oil in compressor air discharge systems.

2. Description of the Prior Art

Gas-liquid separators are used in various applications, but are most notably used to separate oil from air. Air-oil separators are typically used where it is necessary to remove suspended oil mist from an air stream, such as in the air discharge systems of air compressors, vacuum compressors and refrigerant compressors. The separator allows the discharged air to be used without the contamination of the oil which has entered the air in the compressor, and provides for the recovery of the oil so that it can be reused. The air-oil separator is typically mounted in a housing or tank having a separation chamber through which the air flows above an oil reservoir. The separator includes coalescing media through which the discharge air passes while the oil is separated from the air flow. The coalescing media is cylindrically shaped and is typically mounted vertically, that is, in which the axis of the cylindrical coalescing media extends in a vertical direction. A shroud may be provided within the separation chamber around the separator to slow the air

flow and provide a vertical direction to the air flow as it encounters the separator. The contaminated air usually enters the separation chamber from outside the air-oil separator and flows into the center of the separator where it then flows axially out of the separation chamber. As the air flows radially through the layers of the separator, the oil coalesces and collects in the interior of the separator where it can be syphoned off or drained into the reservoir, typically by means of a scavenging system, so that it can be reused. The flow directions may also be reversed in which contaminated air is introduced into the center of the air-oil separator and flows radially outwardly through the separator with the oil coalescing and collecting on the outside of the separator where it drains into a reservoir. An example of a prior art air-oil separator is shown in U.S. Patent No. 4,878,929.

The characteristics of the air flow and the size of the separator are limited by the cylindrical configuration of the separator. For example, where the air flows from the outside of the separator into the separator and a shroud is used around the separator in the separation chamber, the air must flow through the narrow annular chamber between the shroud and the outside of the separator before it enters the separator. This annular chamber has a constant cross section, but the air volume decreases through this chamber since some of the air enters the separator, and thus the air velocity decreases toward the top of the separator. Since sufficient clearance must be provided between the shroud and the outside of the separator, particularly at the bottom of this annular chamber, the size of the separator, and thus the effective surface area provided by the separator, is limited by the size of the shroud.

SUMMARY OF THE INVENTION

The present invention provides advantages over the prior art designs of air-oil separators that have not been realized heretofore. The present invention provides an air-oil separator which is generally conically shaped, providing a greater effective surface area over the same axial length than the prior art cylindrically shaped separators, since the generally conically shaped separator can be made with a larger diameter at the upper end while still providing sufficient clearance from the shroud at the lower end.

The air-oil separator of the present invention also provides a funnel type action to direct the flow of scavanged oil into a pool or reservoir where the oil can be more easily collected. This feature may be particularly advantageoūs when the separator is mounted in a horizontal orientation, that is, in which the axis of the separator extends horizontally. In this configuration, the prior art cylindrical separator collected oil along the bottom portion of the separator, and, since the separator extended horizontally, the oil tended to accumulate in this portion of the separator and not readily to drain off. Because the generally conically shaped separator of the present invention has a sloped bottom surface when mounted horizontally, the oil more readily drains from the separator and does not tend to collect in the bottom portion of the separator and inhibit separator performance. As a result, the separator has a longer life because it is not contaminated with accumulated oil.

The generally conically shaped air-oil separators of the present invention may be used in existing oil reservoir tank designs, thus eliminating the need for modification. They may also be used in an inventive new oil tank design which utilizes the advantages of the generally conically shaped separators.

These and other advantages are provided by the present invention of a liquid reservoir tank including a gas-liquid separator, comprising a tank body having an open end, a portion of the tank body forming a liquid separation chamber, another portion of the tank body forming a liquid reservoir; a tank cover covering the open end of the tank body, the tank body and the tank cover providing a gas inlet and a gas outlet with a gas flow through the separation chamber from the gas inlet to the gas outlet; and a gas-liquid separator mounted in the separation chamber in the gas flow between the gas inlet and the gas outlet, the separator comprising a coalescing stage layer and a drain stage layer arranged radially symmetrically about an axis extending through the interior of the separator, one of the layers positioned within the other of the layers, the coalescing stage layer being upstream of the drain stage layer, each of the layers being generally frusto-conical in shape whereby both of the layers are closer to the axis at one end than at the other end.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top plan view of an oil reservoir tank assembly with an air-oil separator according to the present invention.

FIG. **2** is a side sectional view of the oil reservoir tank assembly taken along line **2**—**2** of FIG. **1**.

FIG. **3** is a detailed side sectional view of a portion of the air-oil separator of FIG. **2**.

FIG. **4** is a top plan view of another oil reservoir tank assembly with an air-oil separator according to another embodiment of the present invention.

FIG. **5** is a side sectional view taken along line **5**—**5** of FIG. **4**.

FIG. **6** is an end sectional view taken along line **6**—**6** of FIG. **5**.

FIG. **7** is a detailed side sectional view of a portion of the air-oil separator of FIG. **5**.

FIG. **8** is an end elevational view of yet another oil reservoir tank assembly with an air-oil separator according to another embodiment of the present invention.

FIG. **9** is a side sectional view taken along line **9**—**9** of FIG. **8**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawings and initially to FIGS. **1** and **2**, there is shown an oil tank assembly **10** according to the present invention. The tank assembly shown and described herein is only one of many arrangements in which the present invention may be used, and the tank and separation configuration may be altered significantly without affecting the present invention. The tank assembly **10** comprises a body **11** having a reservoir **12** formed at the bottom for collection of oil removed by in the oil separation process. The upper portion of the body **11** forms a separation chamber **13**. The top of the separation chamber **13** is enclosed by a tank cover **14** which is attached to the body **11** by a plurality of bolts **15** or other suitable fastening devices. A tank seal or gasket **16** is proved around the upper rim of the body **11**, between the body and the tank cover. Preferably, the tank seal **16** comprises an O-ring provided in a corresponding groove in the bottom of the tank cover **14** and another O-ring provided in a corresponding groove on the top of the upper rim of the tank body **11**. An air inlet **17** is provided on one side of the body **11** for air to enter the separation chamber **13**. The air flows from the separation chamber through a passage (not shown) in the tank cover **14** and through an air outlet **18** provided in the tank cover.

Within the separation chamber **13** is a generally cylindrical shroud **20** which diverts the incoming air flow from the air inlet **17** and causes the air to flow down and around the shroud. This provides a first stage air-oil separation, in that, large droplets of oil are separated by the abrupt change in air flow and these oil droplets fall into the reservoir **12**. A safety valve **19** is also provided in the body **11** extending through the shroud **20**. The safety valve **19** is a pressure relief valve which opens in the event that air pressure inside the shroud **20** increases above a predetermined level. The air flow then passes upwardly and axially inwardly, through an air-oil separator **21** comprising two generally conically shaped or generally frusto-conically shaped layers **22** and **23**.

The upstream layer **22** is a coalescing stage layer. The downstream layer **23** is a drain stage layer. In the embodiment shown in FIG. **2** in which the flow of air is from the outside to the inside of the air-oil separator **21**, the coalescing stage layer **22** is on the outside of the drain stage layer **23**, and the drain stage layer is inside the coalescing stage layer. The layers **22** and **23** are each preferably made of a molded or formed media so that they can be readily shaped into the desired conical or frusto-conical configuration. A pleated or wrapped media may also be used. The layers are comprised of any suitable combination of materials used in air-oil separation, such as fiberglass, polyester, polypropylene or metal, some of which may be pleated in a conventional manner, or which may be molded, formed, wrapped or otherwise shaped. As shown in FIG. **3**, the air-oil separator also preferably includes an outer wrap layer **25** on the exterior of the separator, and a support member **26** along the interior surface of the layer **22**.

The layers **22** and **23**, along with the layers **25** and **26**, are assembled into an air-oil separator unit **21** which is mounted in the separation chamber **13** within the shroud **20**. The lower ends of each of the layers **22**, **23**, **25** and **26** are set in a hardenable sealing material, such as urethane, epoxy or plastisol, which is molded

in place in a generally circular, lower connection plate **24**. The lower ends of the layers **22**, **23**, **25** and **26** are thus sealed to the lower connection plate **24,** and fluid is prevented from flowing into or out of the interior of the separator, except through the layers. Alternatively, in place of the metal connection plate **24**, the bottom ends of the layers **22**, **23**, **25** and **26** can be inserted into a plastic end cap made of a moldable plastic or elastic material such as polyurethane, which is molded in place; such a bottom end cap seals and holds the layers in position without a supporting metal connection plate. The upper ends of the layers **22**, **23**, **25** and **26** are set in a similar hardenable sealing material molded in an upper mounting plate assembly **27,** a portion of which extends radially outwardly from the layers. As shown in FIG. **3**, the assembly **27** comprises an inverted trough portion **28** which surrounds the hardenable material in which the ends upper ends of the layers **22**, **23**, **25** and **26** are set, and a flange portion **29** which extends between the upper rim of the body **11** and the tank cover **14** and is secured in place by the connection of the tank cover on the tank body. The portions **28** and **29** are attached together, such as by welding. The upper ends of the layers **22**, **23**, **25** and **26** are thus sealed to the upper mounting plate **27,** and fluid is prevented from flowing into or out of the interior of the separator, except through the layers. Alternatively, in place of the upper mounting plate assembly **27**, an integrated upper end cap and flange may be formed in accordance with the disclosure of U.S. Patent Applications Serial Nos. 09/174,137 and 09/174,139, the disclosures of which are hereby incorporated by reference in their entireties.

A scavenging tube **30** extends downwardly from the tank cover 14 into the separation chamber inside the drain stage layer **23**. Oil draining from the layer **23** can be withdrawn therefrom using the drain tube **30**.

Unlike the generally cylindrical air-oil separators of the prior art, the layers **22** and **23** of this invention are generally conically shaped, or frusto-conically

shaped, providing a larger amount of active surface area per axial length of the separator element, and providing a funnel type shape into which the scavenged oil may flow to be withdrawn through the tube **30** using a conventional oil scavenging system.

The tank assembly **10** shown in FIGS. **1-3** is designed to allow the incorporation of the generally conically shaped air-oil separators in an otherwise conventionally designed air-oil separator. The uniquely shaped separators may also be incorporated into an tank assembly designed specifically for their use, and such a tank assembly **110** is shown in FIGS. **4-7**. The tank assembly **110** has a body **111**, a reservoir **112**, a separation chamber **113**, a tank cover **114**, tank cover bolts **115**, a tank seal **116**, an air inlet **117**, an air outlet **118**, a safety valve **119**, a shroud **120**, and an air-oil separator **121** comprising a coalescing stage layer **122** and a drain stage layer **123**, each of which is generally similar to the body **11**, the reservoir **12**, the separation chamber **13**, the tank cover **14**, the tank cover bolts **15**, the tank seal **16**, the air inlet **17**, the air outlet **18**, the safety valve **19**, the shroud **20**, the air-oil separator **21**, the coalescing stage layer **22** and the drain stage layer **23** already described.

Unlike the layers **22** and **23** of FIGS. **2** and **3**, the coalescing stage layer **122** and the drain stage layer **123** are each made as separate modules which can be individually removed. Each of the elements **122** and **123** is mounted at each end in integrated seals which can be made of urethane or any suitable material. Unlike the air-oil separator **21** of FIGS. **1-3**, the air-oil separator is not assembled into an integrated unit. Instead, each of the elements **122** and **123** is separate and can be individually replaced as needed. The drain stage element **123** is self supporting. The coalescing stage element **122** is mounted in a frame the bottom of which is attached to a scavenge flow drain tube **130** which extends through the reservoir **112**. At the bottom of the tube **130** is a scavenged oil return port **132**.

While the air-oil separator of this invention has been described with reference to an oil tank having an outside-in air flow, that is, in which the air flows radially from outside the separator to the interior of the separator, it should be understood that the separator provides equal advantages when the air is flowing the opposite direction. Instead of air entering the oil tank assembly **10** through the inlet **17** and exiting through the outlet **18**, the air flow may be reversed with the air entering the oil tank through the passage **18** and exiting through the passage **17**. The air-oil separator provides the same advantages under these circumstances. Likewise, while the air-oil separator of this invention has been described with reference to a separator which is mounted vertically in an oil tank assembly, that is in which the axis of the separator extends vertically, the advantages of the separator of this invention can also be realized in configurations in which the separator is mounted horizontally.

FIGS. **8** and **9** shows a tank assembly **210** which incorporates both inside-out air flow and a horizontally mounted air-oil separator. The tank assembly **210** has a body **211**, a reservoir **212**, a separation chamber **213**, a tank cover **214**, tank cover bolts **215**, a tank seal **216**, a shroud **220**, and an air-oil separator **221** comprising a drain stage layer **223** and a coalescing stage layer **222**, each of which is generally similar to the body **11**, the reservoir **12**, the separation chamber **13**, the tank cover **14**, the tank cover bolts **15**, the tank seal **16**, the shroud **20**, the drain stage layer **23** and the coalescing stage layer **22** already described.

Unlike the previously described embodiments of the invention, the separator of FIGS. **8** and **9** uses an inside-out flow, with an air inlet **217** is provided in the tank cover **214** and an air outlet **18** is provided in the tank body **211** on the top of the tank. Therefore, the coalescing stage layer **222** of the separator is provided inside the drain stage layer **223**, and the oil drains from the separator into the reservoir **212**. Since the generally conically shaped air-oil separator **221** of this embodiment does not have layers which extend completely horizontally, oil does not tend to

accumulate along the bottom of the separator. Instead, the sloped configuration of the bottom of the separator facilitates the drainage of the oil from the separator so that it falls more readily into the reservoir **212**.

While the layers of the air-oil separator of this invention have been described as being generally conical or generally frusto-conical, this is intended to include layers which have pleats or soft pleats or ribs, and thus do not have smooth inner or outer surfaces. It is contemplated that layers having such pleats or ribs which are then generally formed into a conical or frusto-conical shape, rather than a cylindrical shape, would realize the advantages of the present invention.

Other variations and modifications of the specific embodiments herein shown and described will be apparent to those skilled in the art, all within the intended spirit and scope of the invention. While the invention has been shown and described with respect to particular embodiments thereof, these are for the purpose of illustration rather than limitation. Accordingly, the patent is not to be limited in scope and effect to the specific embodiments herein shown and described nor in any other way that is is inconsistent with the extent to which the progress in the art has been advanced by the invention.

CLAIMS

What is claimed is:

1. A liquid reservoir tank assembly including a gas-liquid separator, comprising:

a tank body having an open end, a portion of the tank body forming a liquid separation chamber, another portion of the tank body forming a liquid reservoir;

a tank cover covering the open end of the tank body, the tank body and the tank cover providing a gas inlet and a gas outlet with a gas flow through the separation chamber from the gas inlet to the gas outlet; and

a gas-liquid separator mounted in the separation chamber in the gas flow between the gas inlet and the gas outlet, the separator comprising a coalescing stage layer and a drain stage layer arranged radially symmetrically about an axis extending through the interior of the separator, one of the layers positioned within the other of the layers, the coalescing stage layer being upstream of the drain stage layer, each of the layers being generally frusto-conical in shape whereby both of the layers are closer to the axis at one end than at the other end.

2. A liquid reservoir tank assembly as in claim **1,** wherein the axis of the separator extends vertically, the separator is suspended in the separator chamber, and the layers are closer to the axis at the bottom of the separator than at the top.

3. A liquid reservoir tank assembly as in claim **1,** wherein the axis of the separator extends horizontally.

4. A liquid reservoir tank assembly as in claim **1,** wherein the gas flows from the exterior of the gas-liquid separator radially inwardly toward the interior axis of the separator, and the drain stage layer is inside the coalescing stage layer.

5. A liquid reservoir tank assembly as in claim **1,** wherein the layers are separately removable from the tank.

6. A liquid reservoir tank assembly as in claim **1,** comprising in addition a shroud around the separator in the separation chamber.

7. A liquid reservoir tank assembly as in claim **6,** wherein the gas inlet is along a side of the tank body adjacent to the shroud.

8. A liquid reservoir tank assembly including a gas-liquid separator, comprising:

a tank body having an open end, a portion of the tank body forming a liquid separation chamber, another portion of the tank body forming a liquid reservoir;

a tank cover covering the open end of the tank body; and

a gas-liquid separator mounted in the separation chamber, the separator comprising a coalescing stage layer and a drain stage layer each arranged radially symmetrically about a vertical axis, one of the layers positioned within the other of the layers, the coalescing stage layer being upstream of the drain stage layer, each of the layers being generally frusto-conical in shape whereby both of the layers are closer to the axis at lower end than at the upper end.

9. A liquid reservoir tank assembly as in claim **8,** wherein the gas flows from the exterior of the gas-liquid separator radially inwardly toward the interior axis of the separator, and the drain stage layer is inside the coalescing stage layer.

10. A liquid reservoir tank assembly as in claim **8,** wherein the layers are separately removable from the tank.

11. A liquid reservoir tank assembly as in claim **8,** comprising in addition a shroud around the separator in the separation chamber, the gas flowing between the inside of the shroud and the outside of the separator before passing through the separator.

12. A liquid reservoir tank assembly as in claim **11**, wherein the gas inlet is along a side of the tank body adjacent to the shroud, the gas flowing from the inlet around the shroud before passing through the separator.

13. A liquid reservoir tank assembly as in claim **8,** comprising in addition scavenging tube extending into the interior of the separator for the removal of liquid accumulating therein.

14. A liquid reservoir tank assembly as in claim **8,** comprising in addition drain tube extending downwardly from the interior of the separator for the drainage of liquid accumulating therein.

15. A liquid reservoir tank assembly including a gas-liquid separator, comprising:

a tank body having an open end, a portion of the tank body forming a liquid separation chamber, another portion of the tank body forming a liquid reservoir;

a tank cover covering the open end of the tank body; and

a gas-liquid separator mounted in the separation chamber, the separator comprising a coalescing stage layer and a drain stage layer each arranged radially symmetrically about a horizontal axis, one of the layers positioned within the other of the layers, the coalescing stage layer being upstream of the drain stage layer, each of the layers being generally frusto-conical in shape whereby the layers are closer to the axis at one end than the other end.

16. A liquid reservoir tank assembly as in claim **15,** wherein the gas flows from the interior of the gas-liquid separator radially outwardly toward the exterior of the separator, and the coalescing stage layer is inside the drain stage layer.

17. A liquid reservoir tank assembly as in claim **15,** comprising in addition a shroud around the separator in the separation chamber.

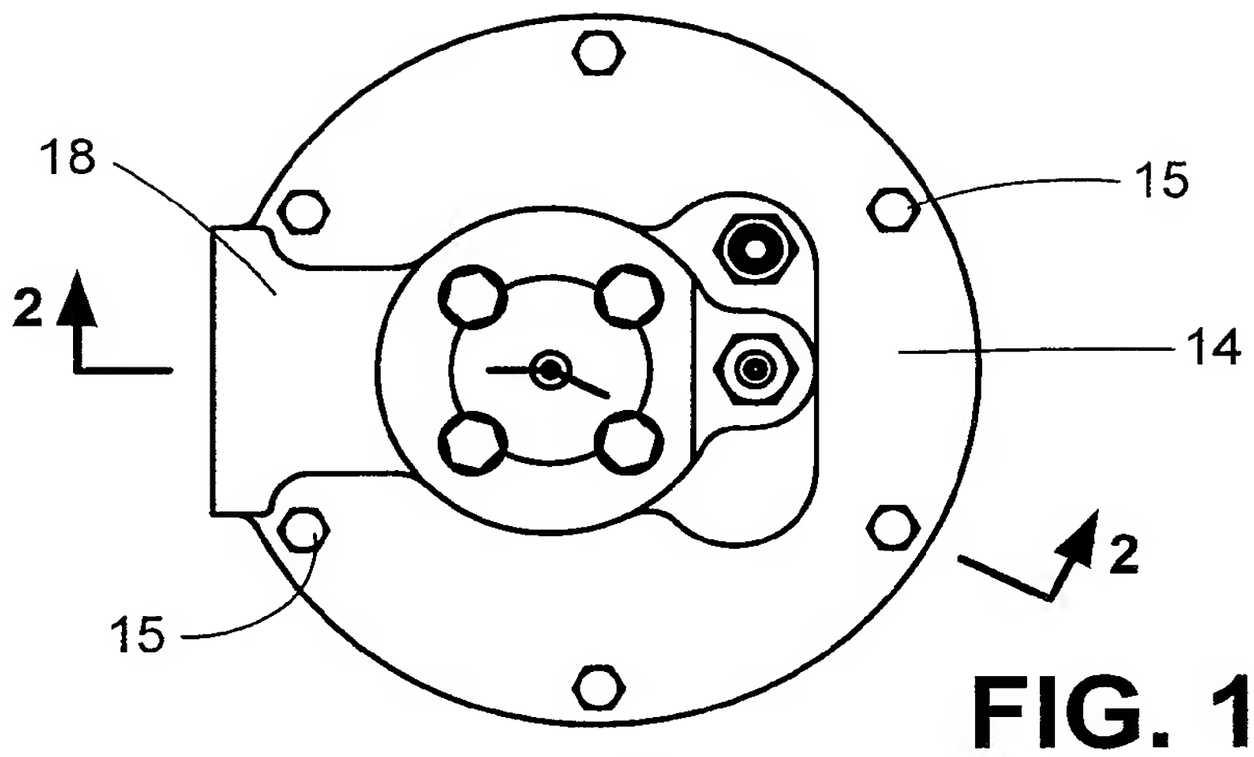

FIG. 1

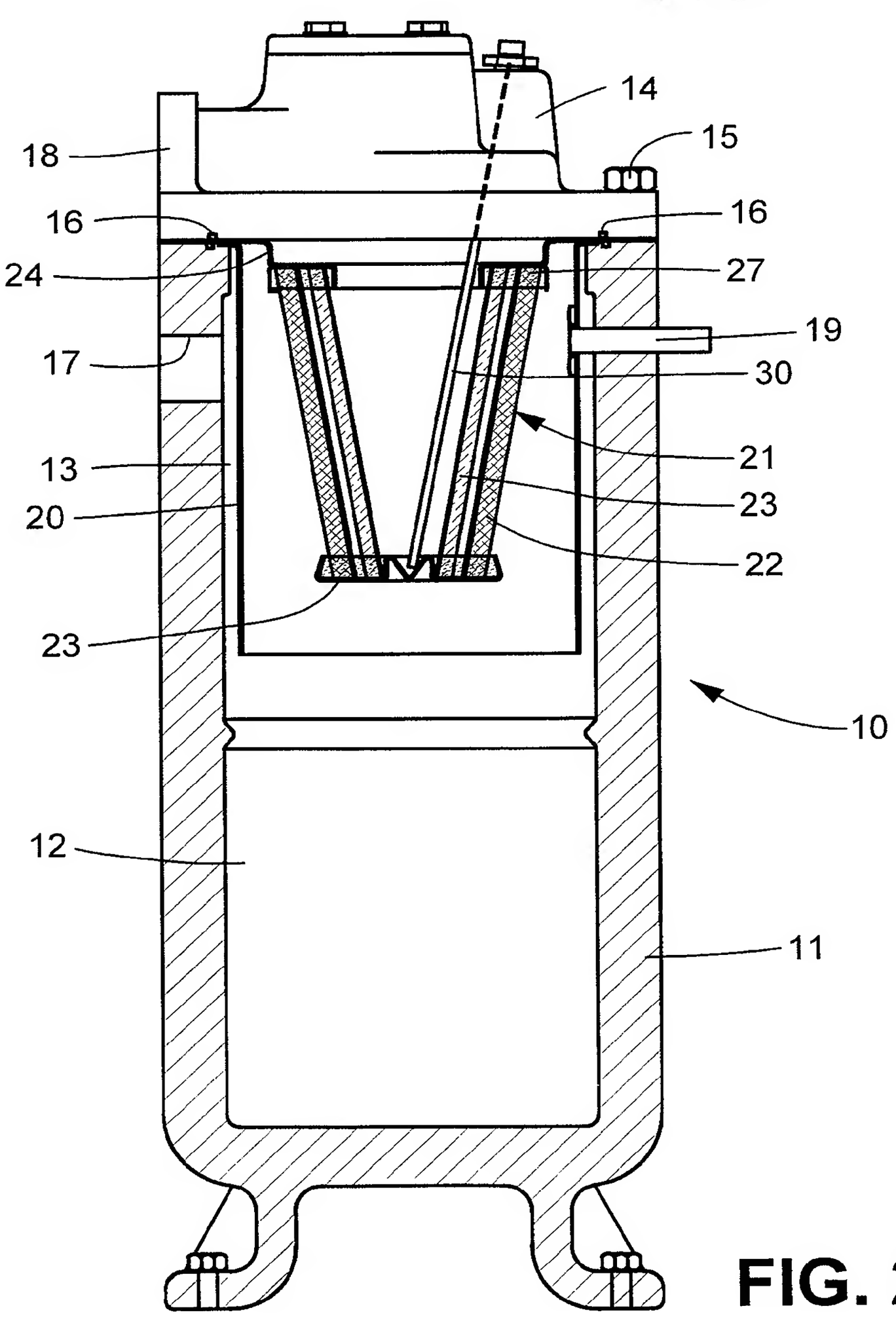

FIG. 2

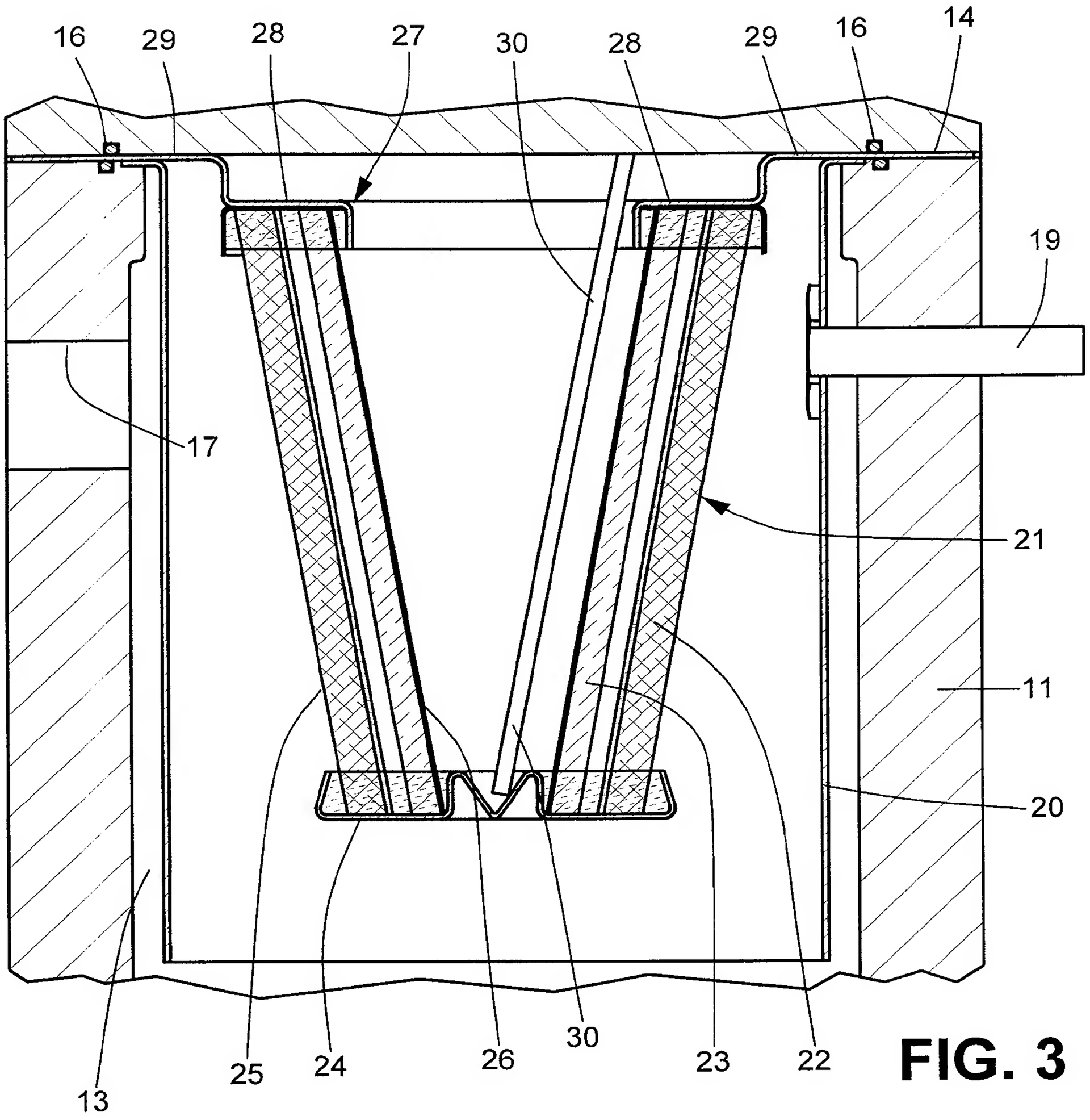

FIG. 3

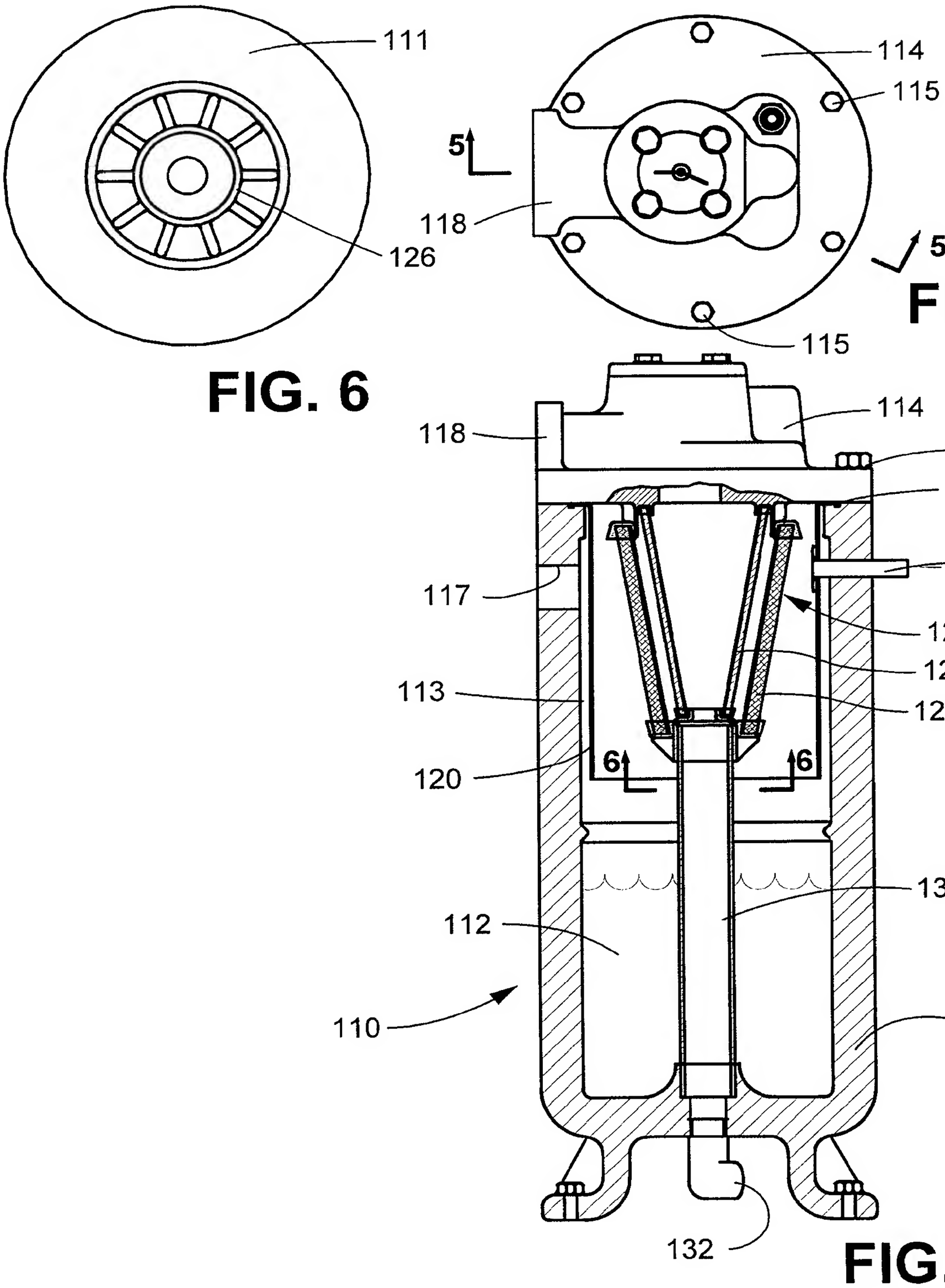
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FIG. 4
FIG. 6
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FIG. 5

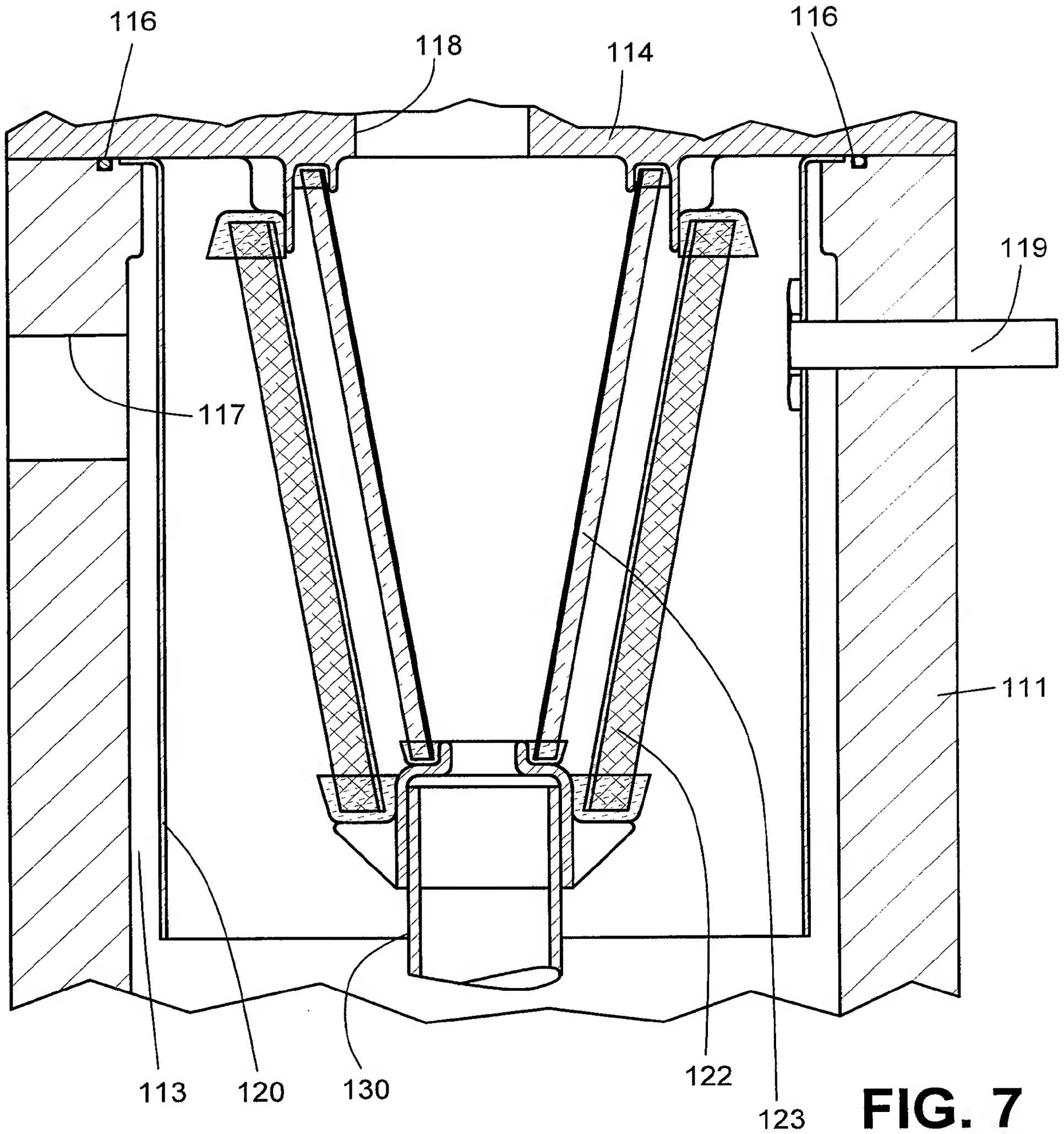

FIG. 7

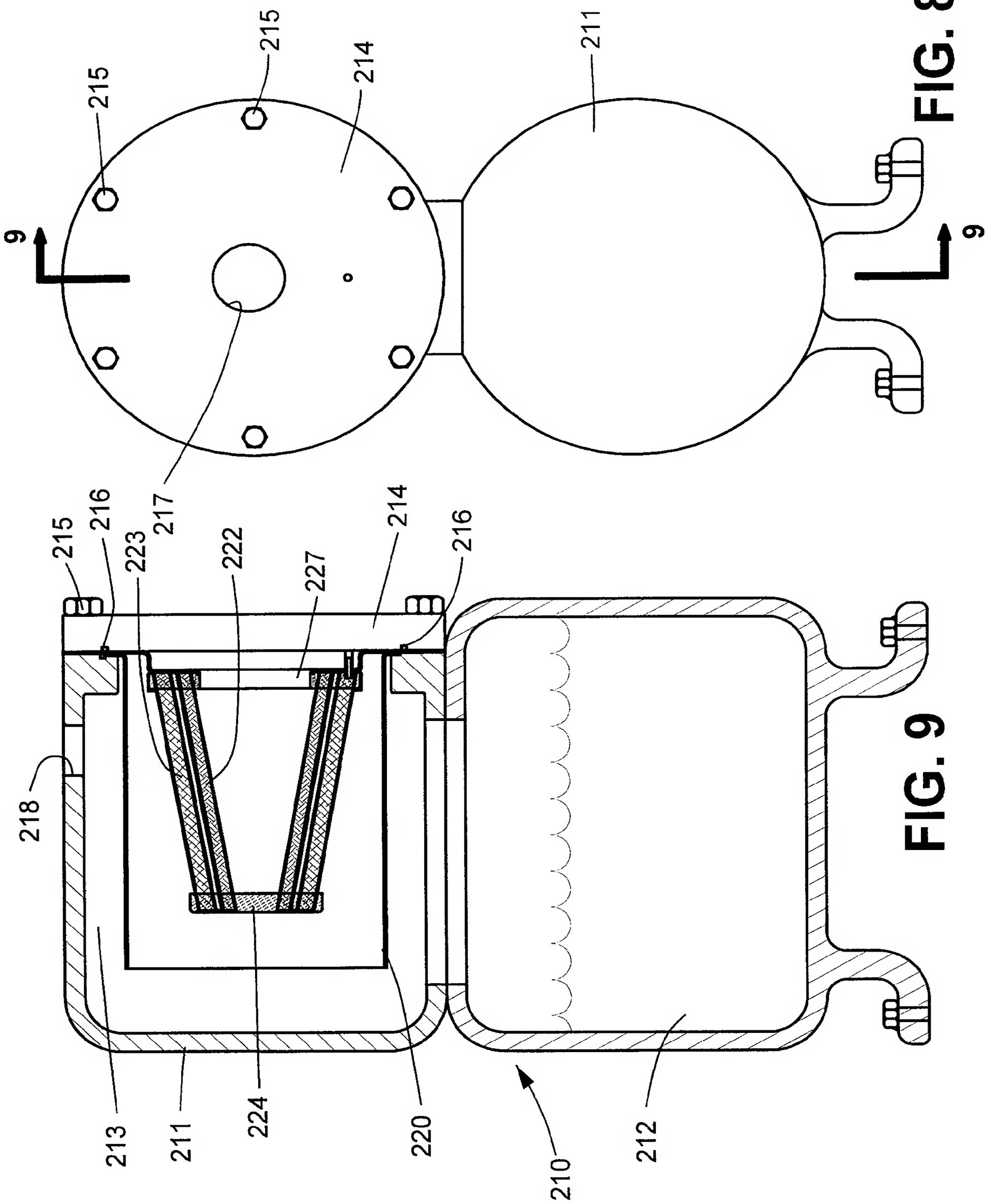
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FIG. 8

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FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/04392

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B01D 46/24
US CL :55/327,330,395,423,486, DIG. 17

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 55/327,330,395,423,486, DIG. 17,319,320,323,392,421,429,466,487

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 1,922,688 A (KAMRATH) 15 August 1933.	1-17
A	US 2,095,586 A (ALGARD) 12 October 1937.	1-17
A	US 3,085,381 A (SOBECK) 16 April 1963.	1-17
A	US 3,364,658 A (WALKER) 23 January 1968.	1-17
A	US 4,878,929 A (TOFSLAND et al.) 07 November 1989.	1-17
A	US 5,129,923 A (HUNTER et al.) 14 July 1992.	1-17

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
08 APRIL 1999	27 APR 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer DUANE S. SMITH Telephone No. (703) 308-0651

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